

Technology Brief 10: Electromagnets

William Sturgeon developed the first practical **electromagnet** in the 1820s. Today, the principle of the electromagnet is used in motors, relay switches in read/write heads for hard disks and tape drives, loud speakers, magnetic levitation, and many other applications.

Basic Principle

Electromagnets can be constructed in various shapes, including the linear **solenoid** and **horseshoe** geometries depicted in Fig. TF10-1. In both cases, when an electric current flows through the insulated wire coiled around the central core, it induces a magnetic field with lines resembling those generated by a bar magnet. The strength of the magnetic field is proportional to the current, the number of turns, and the magnetic permeability of the core material. By using a **ferromagnetic core**, the field strength can be increased by several orders of magnitude, depending on the purity of the iron material. When subjected to a magnetic field, ferromagnetic materials, such as iron or nickel, get magnetized and act like magnets themselves.

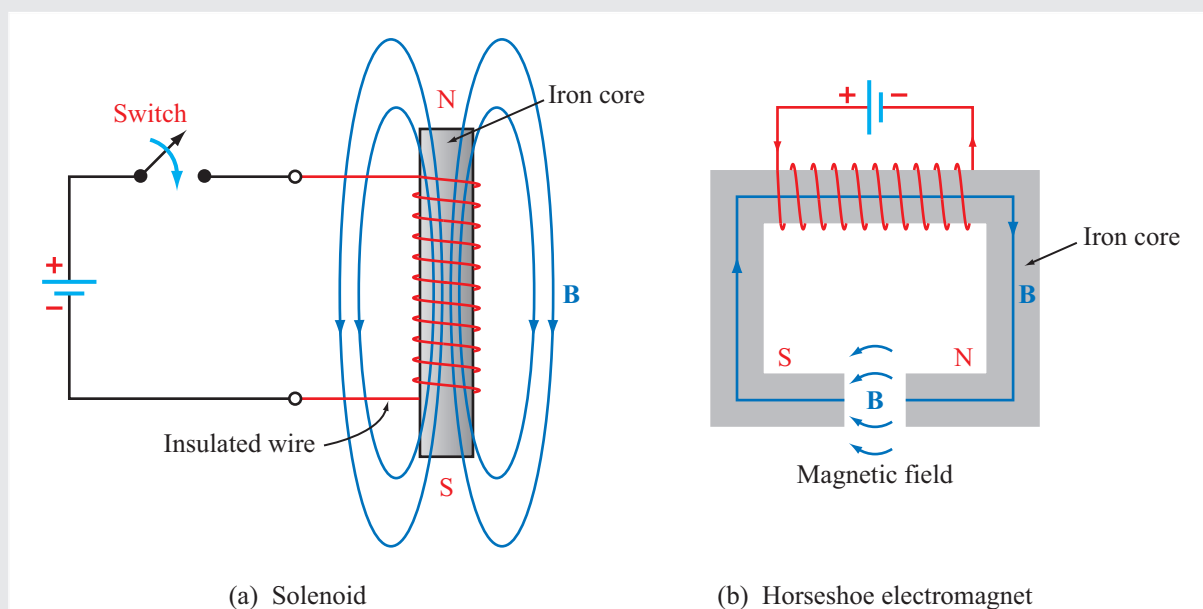
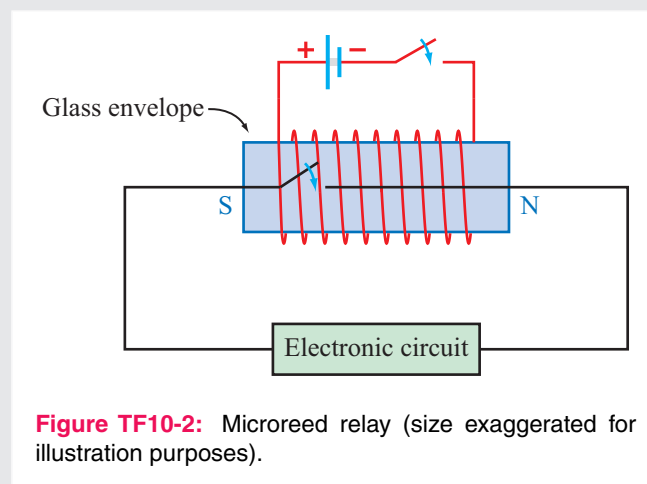


Figure TF10-1: Solenoid and horseshoe magnets.

Magnetic Relays

A magnetic relay is a **switch** or circuit breaker that can be activated into the “ON” and “OFF” positions magnetically. One example is the low-power **reed relay** used in telephone equipment, which consists of two flat nickel–iron blades separated by a small gap (Fig. TF10-2). The blades are shaped in such a way that in the absence of an external force, they remain apart and unconnected (OFF position). Electrical contact between the blades (ON position) is realized by applying a magnetic field along their length. The field, induced by a current flowing in the wire coiled around the glass envelope, causes the two blades to assume opposite magnetic polarities, thereby forcing them to attract together and close out the gap.



The Doorbell

In a doorbell circuit (Fig. TF10-3), the doorbell button is a switch; pushing and holding it down serves to connect the circuit to the household ac source through an appropriate **step-down transformer**. The current from the source flows through the electromagnet, via a contact arm with only one end anchored in place (and the other movable), and onward to the switch. The magnetic field generated by the current flowing in the windings of the electromagnet pulls the unanchored end of the contact arm (which has an iron bar on it) closer in, in the direction of the electromagnet, thereby losing connection with the metal contact and severing current flow in the circuit. With no magnetic field to pull on the contact arm, it snaps back into its earlier position, re-establishing the current in the circuit. This back and forth cycle is repeated many times per second, so long as the doorbell button continues to be pushed down, and with every cycle, the clapper arm attached to the contact arm hits the metal bell and generates a ringing sound.

The Loudspeaker

By using a combination of a stationary, permanent magnet, and a movable electromagnet, the electromagnet/speaker-cone of the loudspeaker (Fig. TF10-4) can be made to move back and forth in response to the electrical signal exciting the electromagnet. The vibrating movement of the cone generates sound waves with the same distribution of frequencies as contained in the spectrum of the electrical signal.

Magnetic Levitation

Magnetically levitated trains [Fig. TF10-5(a)], called *maglevs* for short, can achieve speeds as high as 500 km/hr, primarily because there is no friction between the train and the track. The train basically floats at a height of 1 or more centimeters above the track, made possible by magnetic levitation [Fig. TF10-5(b)]. The train carries superconducting electromagnets that induce currents in coils built into the guide rails alongside the train. The magnetic interaction between the train's superconducting electromagnets and the guide-rail coils serves not only to levitate the train, but also to propel it along the track.

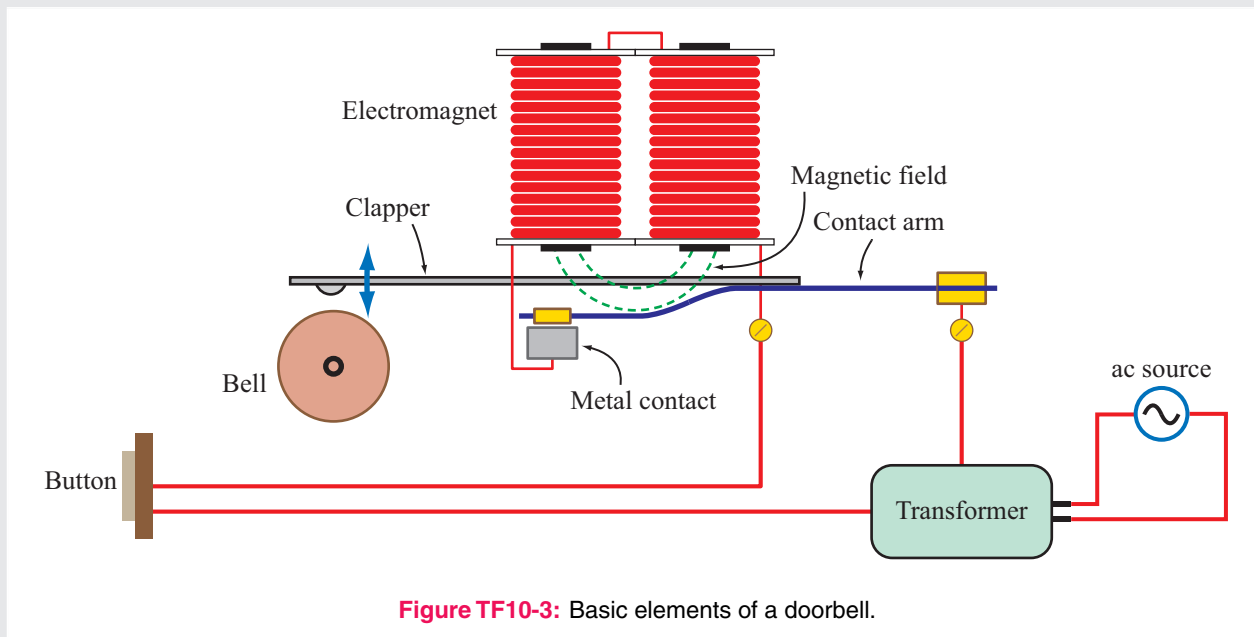
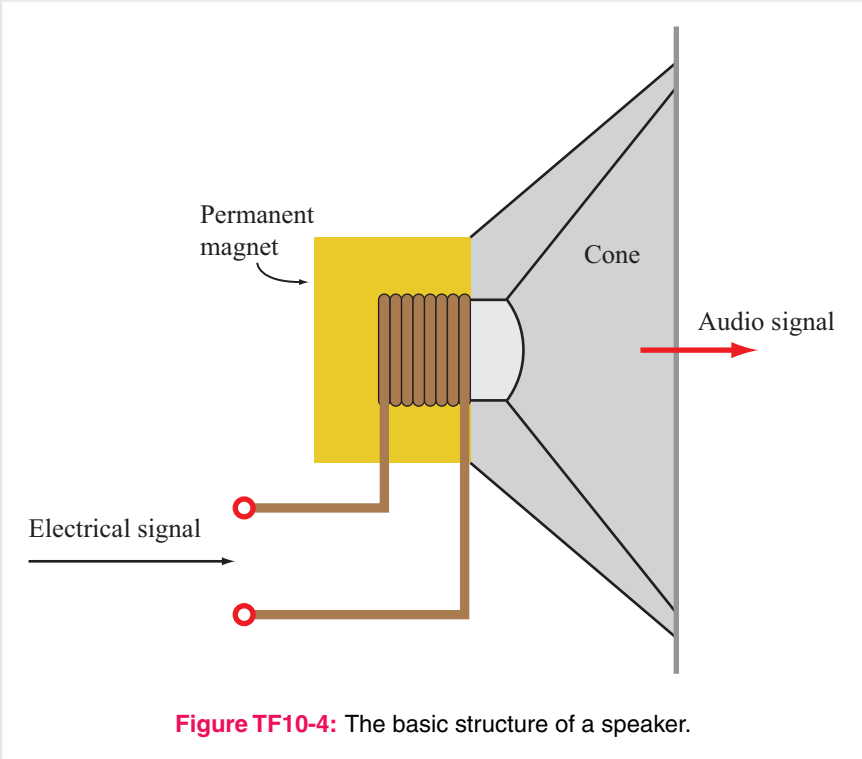
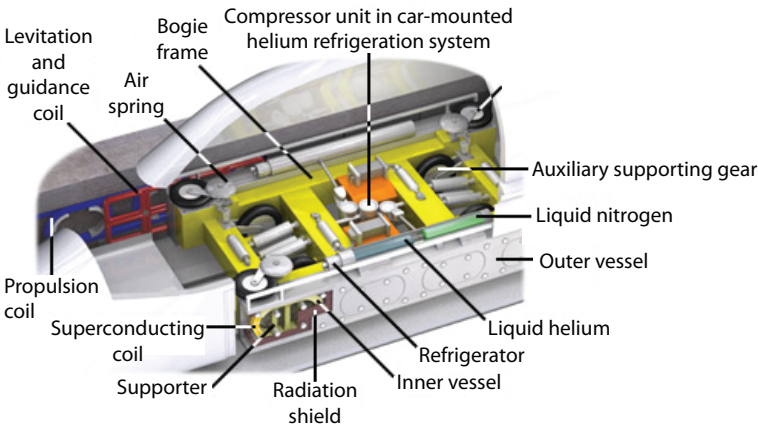


Figure TF10-3: Basic elements of a doorbell.



(a) Maglev train



(b) Internal workings of the Maglev train

Figure TF10-5: Magnetic trains. (Courtesy Shanghai.com.)